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Assessment of Aortic Elasticity and Its Relation with Left Ventricular Filling and Diastolic Parameters by Transthoracic and Transesophageal Echocardiography

Aortik Elastisite ve Aortik Elastisitenin Sol Ventrikül Dolum ve Diyastolik Parametreleri ile İlişkisinin Transtorasik ve Transözofajiyal Ekokardiyografi Değerlendirilmesi

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Abstract

Background: There are limited data comparing aortic dimensions and elastic properties between transthoracic echocardiography (TTE) and transesophageal echocardiography (TEE). Therefore, we aimed to investigate aortic dimensions and indices of aortic elastic properties as well as their relation with left ventricular (LV) filling and diastolic parameters obtained from TTE and TEE.

Method: Forty two patients were included in the study. Aortic dimensions and related elasticity parameters, LV filling and diastolic parameters, left atrial volume index (LAVi), LV mass index were calculated from TTE and TEE recordings in all patients. The correlation analyses were performed for aortic elasticity indices and LV filling and diastolic parameters obtained from TTE and TEE.

Results: There were no significant differences in aortic dimensions and elasticity indexes obtained from TTE and TEE. The correlation analysis revealed that while age E/A, E/E` and LAVi were significantly correlated with aortic elasticity indexes obtained from both TTE and TEE, LV mass index was significantly correlated with only TEE aortic elasticity indices.

Conclusion: When compared to TTE, aortic elastic properties obtained from TEE were more closely related with LV filling and diastolic parameters. In addition, the indexes of aortic function were comparable between TEE and TTE with good intra and interobserver variability.

Keywords: aortic dimensions, transthoracic echocardiography and transesophageal echocardiography.

Özet

Amaç: Aort boyutlar ve elastik özelliklerini transtorasik ekokardiyografi (TTE) ve transözofageal ekokardiyografi (TEE) ile karşılaştıran sınırlı veri vardır. Bu nedenle, TTE ve TEE elde edilen aort boyutlar ve aortik elastik indekslerinin karşılaştırmanın yanı sıra bunların sol ventrikül (LV) dolum ve diyastolik parametreleri ile ilişkisini araştırmayı amaçladık.

Yöntem: Çalışmaya kırk iki hasta dahil edildi. Tüm hastaların TTE ve TEE kayıtlarından aort boyutları ve ilgili elastikiyet parametreleri, sol ventrikül dolum ve diyastolik parametreleri, sol atriyal volüm indeksi (LAVİ), sol ventrikül kütle indeksi hesaplandı. TTE ve TEE elde edilen aort elastikiyeti indeksleri ve sol ventrikül dolum ve diyastolik parametreleri için korelasyon analizi yapıldı.

Bulgular: TTE ve TEE ile elde edilen aort boyutları ve elastikiyeti indeksleri arasında anlamlı bir fark yoktu. Korelasyon analizinde yaş, E / A, E / E`ve LAVİ hem TTE hem de TEE ile edilen aort elastikiyeti indeksleri ile anlamlı derecede ilişkili iken, sol ventrikül kitle indeksi sadece TEE ile elde edilen aort elastikiyeti indeksleri ile ilişkili saptandı.

Sonuç: TTE ile karşılaştırıldığında, TEE elde edilen aortik elastik özellikleri sol ventrikül dolum ve diyastolik parametreleri ile daha yakından ilişkili bulunmuştur. Buna ek olarak, TEE ve TTE ile elde edilen aort fonksiyon indeksleri iyi gözlemci içi ve gözlemciler arası değişkenliği ile benzerdir.

Anahtar Kelimeler: aort boyutları, transtorasik ve transözofageal ekokardiyografi.

Introduction

Impaired aortic elasticity may be cause the increase of afterload. Increasing the afterload can be also increased left ventricular filling pressure and impaired of LV systolic and diastolic function(1-5). Impaired aortic elasticity may contribute to the development of left ventricular diastolic and systolic dysfunction due to increased pulse pressure and left ventricular afterload which results in left ventricular hypertrophy and subendocardial ischemia (6). To quantify the aortic elasticity, many techniques can be used such as transthoracic echocardiography (TTE) or transesophageal echocardiography (TEE), magnetic resonance imaging, and computed tomography (CT)(7-9). However, there are very limited studies related to assessment of aortic elasticity on TEE (10-16). Moreover, in majority of these studies, the elastic properties of aorta were measured on descending aorta in contrast to TTE studies and there were only a few data regarding to elasticity indices of ascending aortic by TEE. In addition, there is no data comparing aortic elastic properties on TTE and TEE and their relation with LV diastolic parameters. The purpose of this study was to compare indices of aortic elastic properties obtained from patients undergoing simultaneous TTE and TEE and to determine their relation with LV diastolic parameters.

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Material and Methods

Study Patients

Forty-two patients underwent a clinically indicated study. The patients with atrial fibrillation, previous ischemic heart disease, LV hypertrophy, left bundle brunch block, pericardial disease, poor image quality and inability to give consent were excluded from the study. TTE and TEE was indicated for 31 patients included in the study for the evaluation of patent foramen ovale, 11 patients for the evaluation of bicuspid aortic valve. The study protocol was approved by the institutional review board, and patients provided a written informed consent.

Transthoracic Echocardiography

Transthoracic echocardiography, with a 2.5 MHz phased-array transducer, was performed using a GE Vivid 7 system (GE Vingmed Ultrasound, Horten, Norway). Three consecutive measurements were obtained and the results were averaged. Recordings were taken in the left lateral decubitus position. The Doppler signals were also recorded at a speed of 100 mm/s and the M-mode traces were recorded at a speed of 50 mm/s (17). Simultaneous electrocardiographic recordings were also taken.

Ascending aorta diameter was measured on the M-mode tracing at 3 cm above the aortic valve. The systolic diameter was measured at the maximal anterior motion of the aorta, whereas the diastolic diameter was measured at the peak of the QRS complex on the simultaneously recorded electrocardiogram. By the biplane Simpson's method LV ejection fraction (LVEF) was calculated. According to the recommendations of the American Society of Echocardiography LV filling and diastolic parameters such as left atrial volume index (LAVi), E, A, Em waves and Deceleration time (DecT) were calculated (18). Besides, LV mass was calculated according to previously suggestions (19).

Transesophageal Echocardiography

TEE, with a 5.0-MHz transesophageal probe, was performed by using a GE Vivid 7 system (GE Vingmed Ultrasound AS, Horten, Norway). TEE was performed after 4 hours fasting period just after transthoracic echocardiography. For posterior pharyngeal anesthesia ten percent lidocain spray was used. The procedure was performed with continuous monitoring of blood pressure, heart rate, one lead ECG and saturation. Ascending aortic elastic parameters was calculated from midesophageal long axis view with approximately 120°. Diameter of the ascending aorta was measured on the M-mode tracing at 3 cm above of the aortic valve. The systolic diameter was measured as previously mentioned at the maximal anterior motion of the aorta, whereas the diastolic diameter was measured at the peak of the QRS complex on the simultaneously recorded electrocardiogram

Aortic Elasticity parameters

For aortic elasticity, following formulas were used (20): aortic strain (%) = [(aortic systolic diameter – diastolic diameter)× 100] / aortic diastolic diameter, aortic stiffness index= ln (systolic pressure / diastolic pressure) / aortic strain, aortic distensibility ($cm2.dyn^{-1}.10^{-6}$) = (2 × aortic strain) / (systolic pressure-diastolic pressure) and aortic elastic modulus ($dyn.cm^{-2}.10^{6}$)= (systolic pressure-diastolic pressure) / aortic strain.

Reproducibility

The intra- and inter-observer variability of aortic dimension measurements were determined for TTE and TEE in all patients. For intraobserver variability, the same observer repeated the measurements after two weeks, whereas interobserver variability was assessed from the measurements by two independent observers.

Statistics

Continuous variables are expressed as mean ±SD. The level of significance was accepted as $p<0.05$. For the normality test of all variables the Kolmogorov-Smirnov test was used. For compare TTE and TEE parameters, independent Student t test or the Mann-Whitney U test was used. Correlation between variables was tested by Pearson or Spearman correlation tests. Interobserver and intraobserver variability assessed by Bland-Altman analysis and intraclass correlation coefficient (ICC). An ICC greater than 0.75 represents excellent reproducibility, whereas values between 0.4 and 0.75 represent fair to good reproducibility (21).

Results

The study population consisted of 42 patients (mean age 36.2±11.9 years and 48% male).. Patients' mean body mass index were 25.5±5.1, mean LV-EF were 64±3.7, mean LV-Mass index were 105±18 and mean LAVi were 25±10.5. The other characteristics were given in table 1 and 2. There were no significant differences between the TTE and TEE in terms of systolic and diastolic blood pressure and heart rate (p=0.32, p=0.42 and p=0.58, respectively).

Table 1. Basic characteristics of the patients.

Age – years	**36.2±11.9**
Male (%)	48
Smoking (%)	24
Hypertension (%)	12
Body mass index (kg/m^2)	25.5±5.1
Body surface Area (m^2)	1.79±0.16
Systolic blood pressure (mmHg)	116±22
Diastolic blood pressure (mmHg)	71±13
Heart rate – per minute	82±12

Table 2. Basic Echocardiographic characteristics of the patients.

Left ventricular ejection fraction (%)	**64±3.7**
Left ventricular Mass index (gr/m^2)	105±18
Left atrial volume index (ml/m^2)	25±10.5
E wave (m/sec)	0.75±0.19
A wave (m/sec)	0.68±0.22
E/A ratio	1.2±0.36
E` wave (m/sec)	0.11±0.03
E/E` ratio	6.7±1.7
Deceleration time (msec)	186±43

There were no significant differences between the TTE and TEE in terms of aortic elasticity parameters (Table 3). There was a moderate correlation with TTE aortic strain E/A, e/e`, LAVi and age, and a weak correlation with LV-Mass-i and DecT. TEE aortic strain showed a moderate correlation with all parameters except for DecT. TTE aortic distensibility had a moderate correlation with E/A, e/e`, LAVi and age, and a weak correlation with LV-Mass-i and DecT. TEE aortic distensibility was shown to have a weak correlation with DecT, a moderate one with LV Mass-i, and a strong one with the other parameters.

Table 3. Comparison of aortic elasticity parameters by TTE and TEE.

Variable	TTE	TEE	p
Aortic systolic diameter (mm)	27.4±2.6	27.3±2.7	0.95
Aortic diastolic diameter (mm)	25.6±2.9	25.9±3.0	0.67
Aortic strain (%)	7.1±4.4	5.5±2.9	0.12
Aortic Distensibility (cm^2.dyn^{-1}.10^{-6})	3.5±3.0	2.5±1.48	0.12
Aortic Elastic modulus (dyn.cm^{-2}.10^6)	8.5±4.3	11±7.3	0.14
Aortic stiffness index	9.2±4.7	11.7±6.8	0.15
Aortic Sclerosis (Grade 0 - %)	76	56	0.13

As for TTE aortic stiffness, a moderate correlation was found with e/e` and LAVi, and a weak correlation with the other parameters. TEE aortic stiffness had a strong correlation with age, a weak correlation with DecT and a moderate correlation with the other parameters. TTE-aortic elastic modulus had a moderate correlation with E/A, e/e`, LAVi and age and a weak correlation with LV-Mass-i ve DecT. TEE-aortic elastic modulus was strongly with age, weakly correlated with DecT and moderately with the other parameters (Table 4). Inter and intraobserver agreement for aortic dimensions obtained from TTE and TEE were good (Table-5).

Discussion

The results of present study demonstrated that indexes of aortic function such as aortic strain, distensibility, stiffness and elastic modulus, obtained by TEE are more correlated LV filling parameters E/A, E/E', LAVi, LV Mass-i than obtained by TTE. To the best of our knowledge, this is the first study that indexes of aortic function by measured TEE as a simple and reliable method for prediction of diastolic dysfunction in people with a normal LVEF. In our study, indexes of aortic function such as aortic stiffness were associated with a prolonged DecT, increased E/A ratio and E/Em ratio suggesting a link between increased aortic stiffness and impaired myocardial

Table 4. Correlation coefficients between aortic elasticity parameters and left ventricular filling pressure-diastolic parameters and age.

Aortic elasticity parameters								
	Strain		Distensibility		Stiffness		Elastic modulus	
	TTE	TEE	TTE	TEE	TTE	TEE	TTE	TEE
E/A	0.43*	0.47*	0.37*	0.50*	-0.19	-0.40*	-0.28*	-0.43*
E/E`	-0.30*	-0.47*	-0.34*	-0.65*	0.28*	0.37*	0.43*	0.45*
DecT	-0.15	-0.19	-0.10	-0.17	0.14	0.21	0.09	0.17
LAVi	-0.41*	-0.45*	-0.43*	-0.53*	0.39*	0.29*	0.38*	0.26*
LVMass-i	-0.19	-0.25*	-0.20	-0.26*	0.14	0.30*	0.07	0.26*
Age	-0.43*	-0.53*	-0.39*	-0.60*	0.13	0.60*	0.26*	0.66*

*P value < 0.05 DecT: Deceleration time, LAVi: Left atrial volume index, LVMass-i: Left ventricular mass index

relaxation. E/A ratio and E/Em ratio are the marker of cardiac diastolic dysfunction, and the changes in E/A ratio seem to precede the changes in the deceleration time of mitral inflow in the early stage of cardiac diastolic dysfunction (18,22). Indexes of aortic function such as aortic distensibility are a more valid marker of arterial stiffness and better predictor of diastolic dysfunction (6,23).

The reflected wave travels more rapidly along the arterial tree in those with arterial stiffness, resulting in an increase in aortic systolic pressure and a decrease in aortic pressure during diastole (7). The resultant increase in afterload during LV systole and reduction in coronary perfusion during LV diastole may lead to LV hypertrophy and slowing of left ventricle relaxation (24). Clinical studies have also linked increased aortic stiffness to overt diastolic heart failure and coronary artery disease extension (7,25-27). Thus, abnormal aortic elastic properties may represent one of the mechanisms of LV diastolic dysfunction in our study population with normal LVEF.

Table 5. Inter and intraobserver agreement for aortic dimension obtained from TTE and TEE.

Dimensions	Intraobserver agreement ICC, 95% CI	Interobserver agreement, Mean difference, 95% CI
TTE-Aortic systolic	0.96 (0.91-0.98)	-0.03 (0.31, -0.37)
TTE-Aortic diastolic	0.94 (0.87-0.97)	-0.09 (0.17, -0.35)
TEE-Aortic systolic	0.92 (0.83-0.97)	-0.07 (0.38, -0.52)
TEE-Aortic diastolic	0.90 (0.78-0.96)	0.03 (0.33, -0.27)

Also, we showed that indexes of aortic function such as aortic stiffness were associated with age. Dilatation of blood vessel occurs not only normally with aging, but in addition, elastic properties of the arterial vessel wall decrease with advancing age (28,29). Lipid deposits and lipid metabolism in arterial walls accelerate elastic fiber destruction during the process of atherosclerosis, thus further reducing the distensibility of the aorta. Since the destroyed elastic fibers are replaced with collagen fibers, the stiffness of the aorta increases, thereby greatly affecting not only cardiovascular dynamics, but also cardiac function. Furthermore, the calcium content of the aorta that is observed in atherosclerosis also reduces the distensibility of the aorta (30).

In conclusion, aortic elastic properties obtained from TEE were more closely related with LV filling and diastolic parameters than aortic elastic properties obtained from TTE. In addition, the indexes of aortic function were comparable between TEE and TTE with good intra- and interobserver variability.

Limitations

The most important limitations of the present study are the low number of participants and not being used of TEE in routine clinical practice frequently. However, the implication of our study is that when compared to TTE aortic elasticity parameters, TEE aortic elasticity parameters were better reflects the LV diastolic function in patients who underwent TEE for any reason. Besides, non-invasive measurement of blood pressures from brachial artery could be accepted as a limitation, however in the clinical setting, it can-not be feasible to have invasively measured central pressure. Moreover, assessment of E/A and E/Em in patients with normal EF have some limitations.

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